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(54) **COOLING DEVICE FOR VEHICLE HEADLIGHTS**

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F21S 8/10 (2006.01)

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USPC 362/101, 249.01, 249.02, 294, 373, 362/345, 507, 516, 538, 359, 544, 545, 547
See application file for complete search history.

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(74) *Attorney, Agent, or Firm* — Sughrue Mion, PLLC

(57) **ABSTRACT**

A cooling device for cooling an LED of vehicle headlight without restricting a design of a housing is provided. The cooling device is comprised of an LED held in a housing sealed with a lens, a reflector that reflects a light emitted from the light source, a heat collector on which the LED is mounted, a heat sink disposed behind the reflector, and a pair of heat pipes thermally connecting the heat collector and the heat sink. The heat sink is arranged inside of the housing.

8 Claims, 14 Drawing Sheets

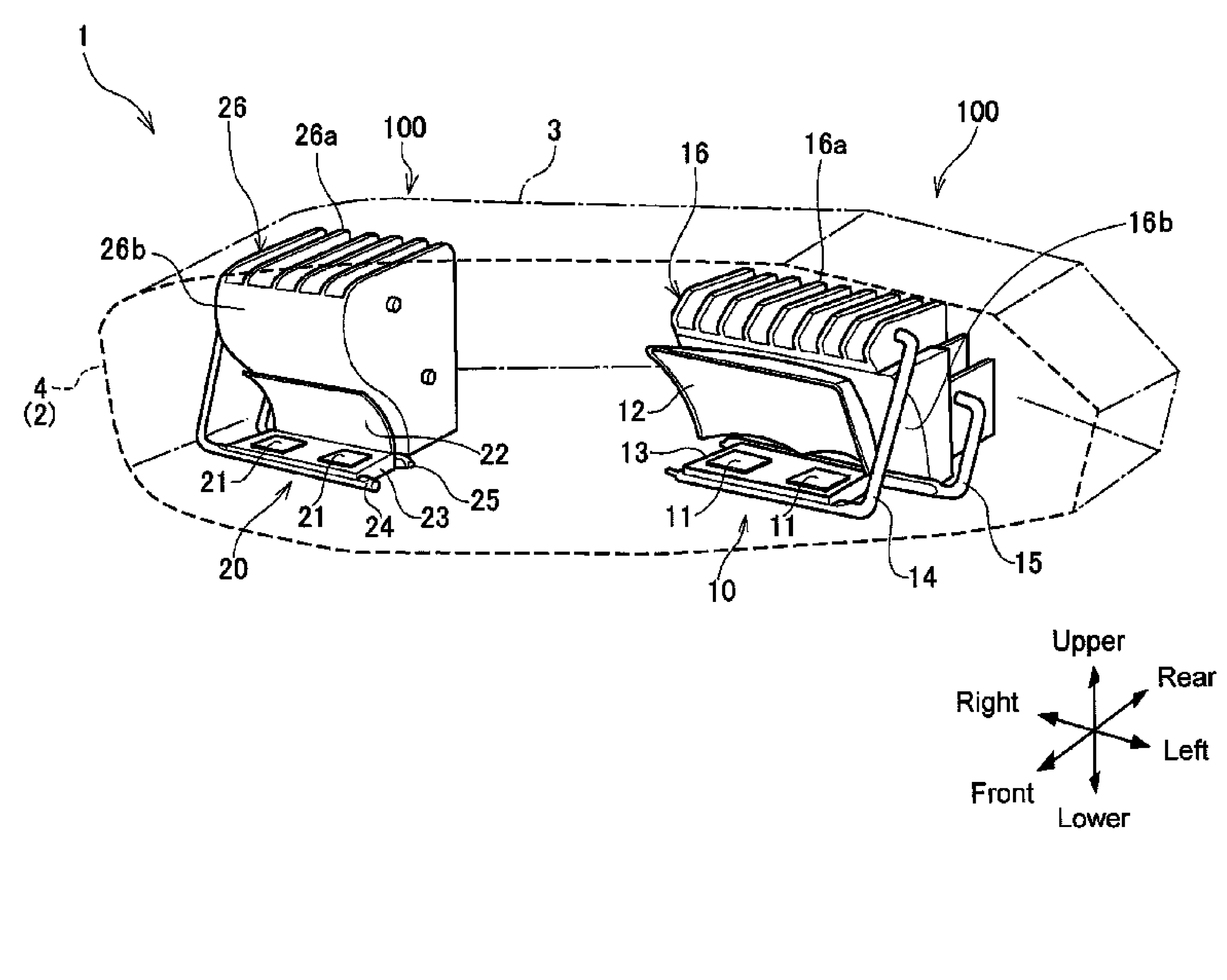

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Fig. 1

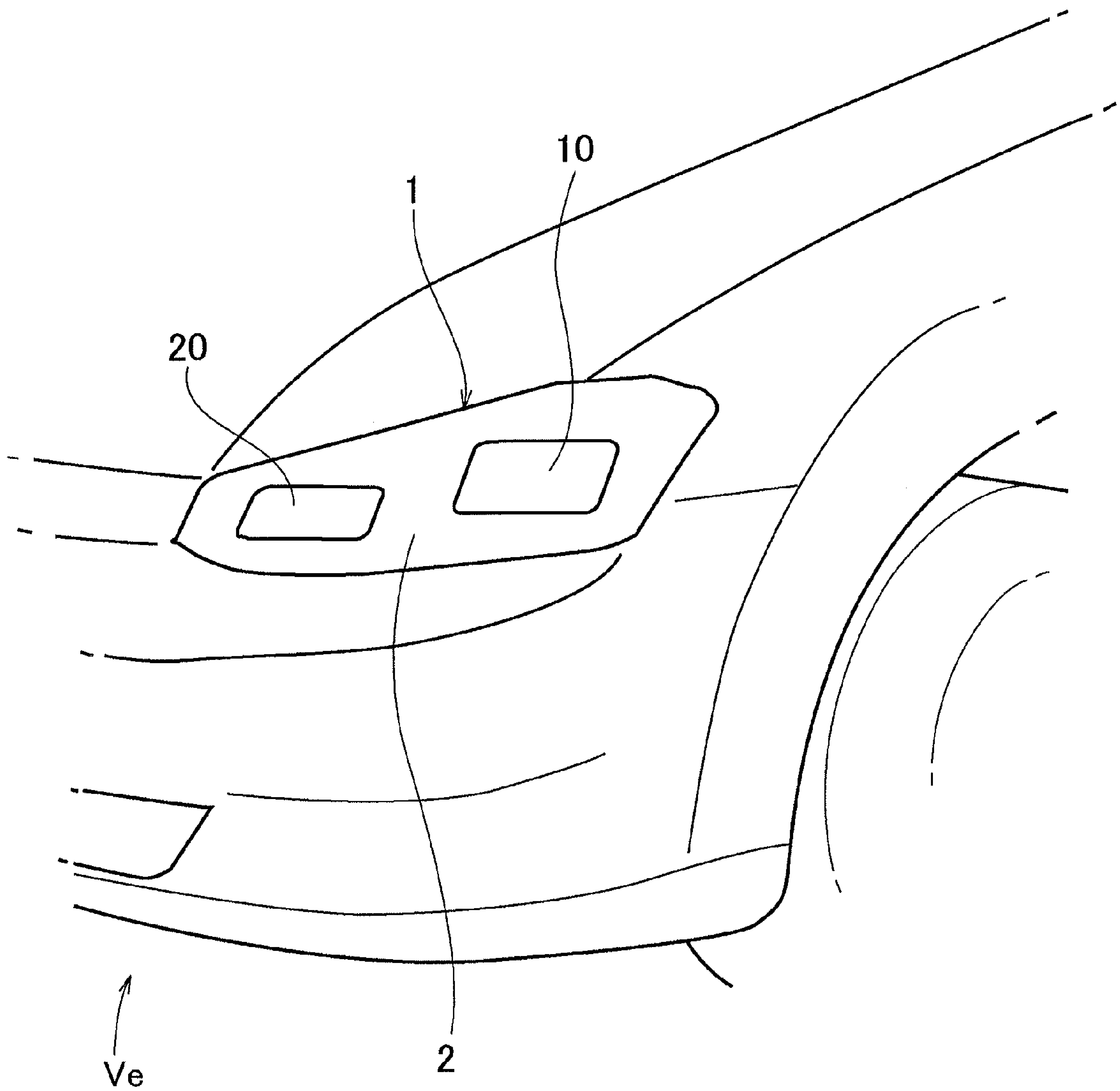
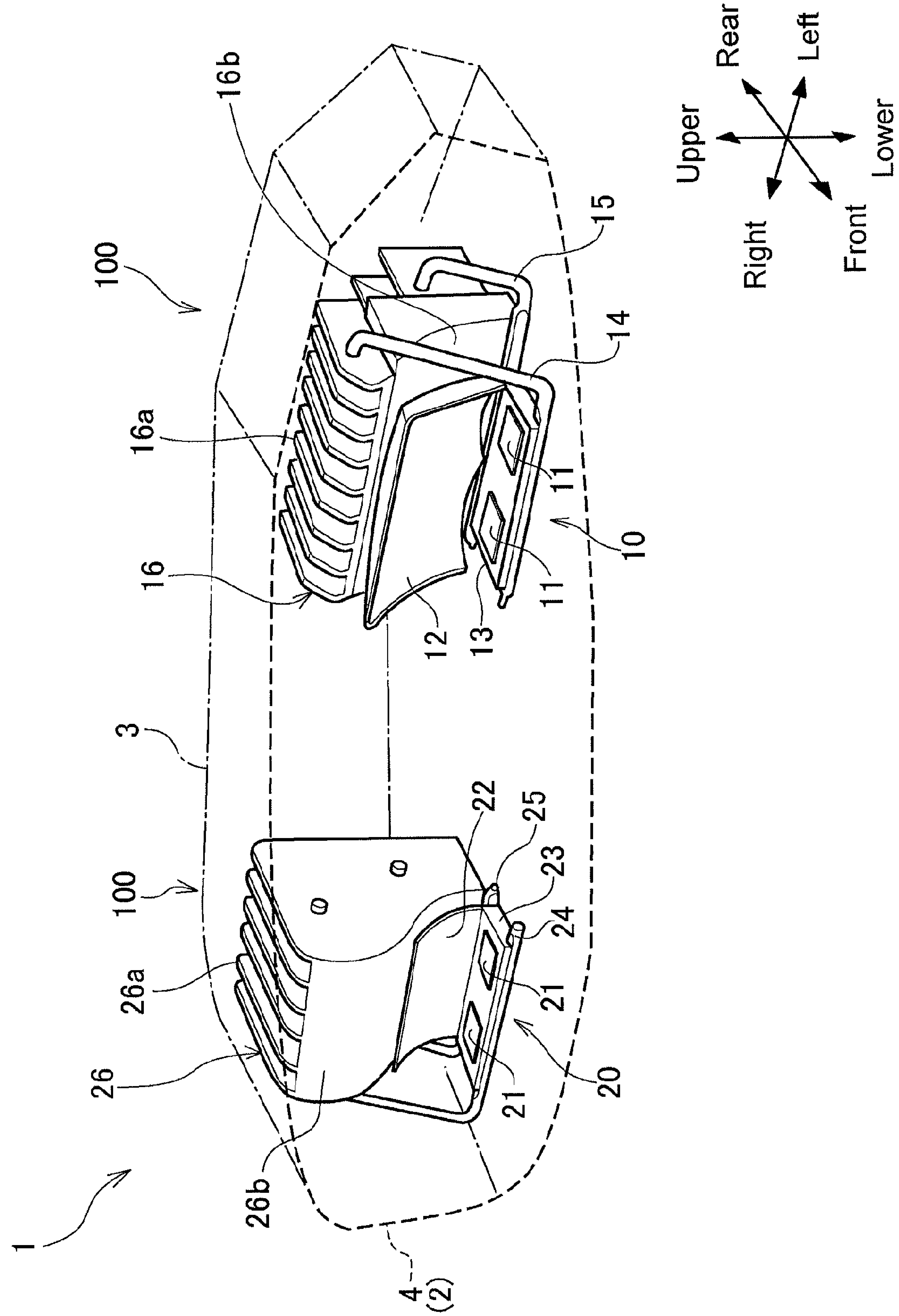


Fig. 2



Rear
Left
Upper
Lower
Right
Front
100
16b
15
14
16a
11
11
10
16
12
13
3
22
25
23
24
100
26a
21
21
20
26
26b
1
4
(2)

Fig. 3

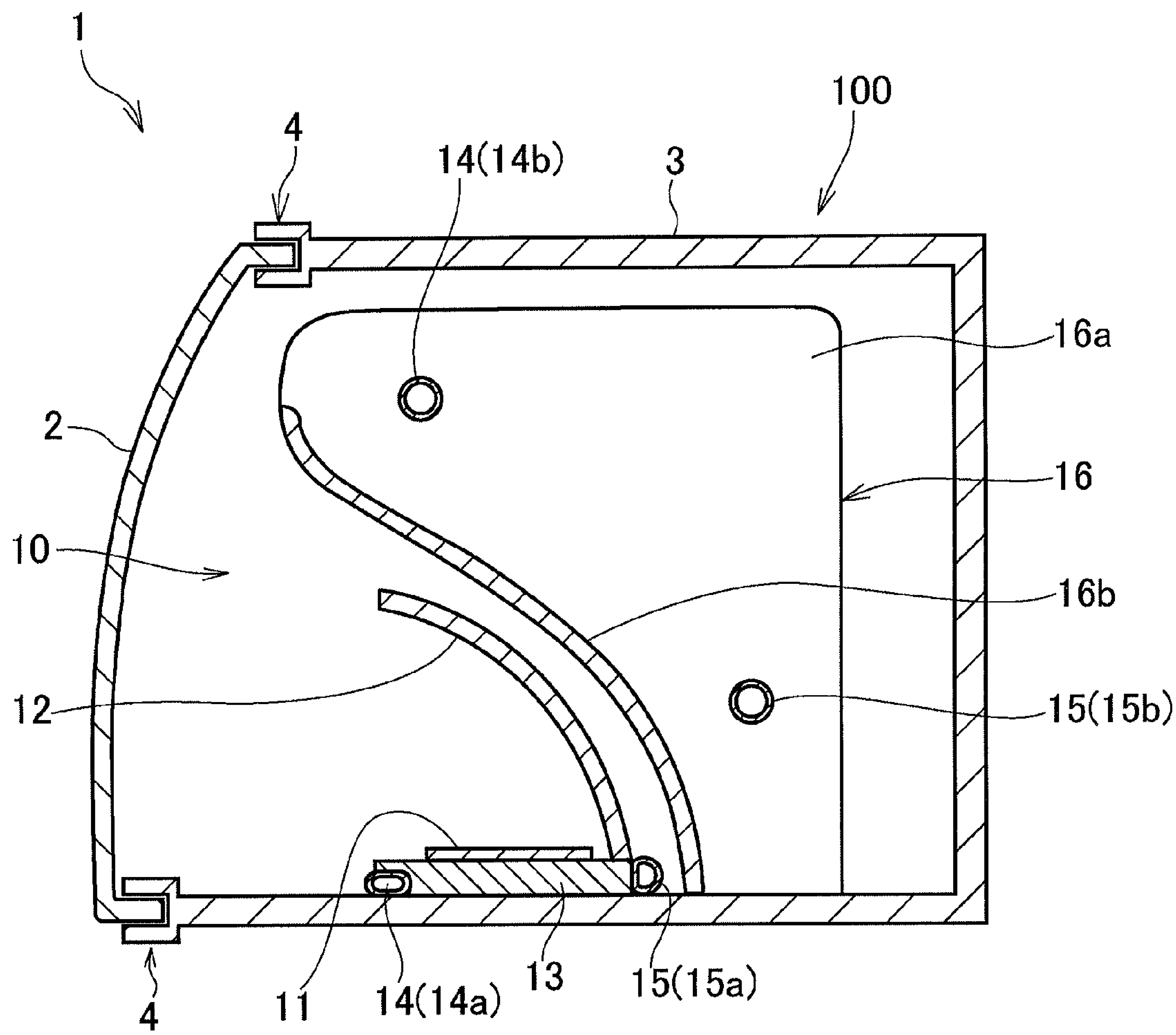
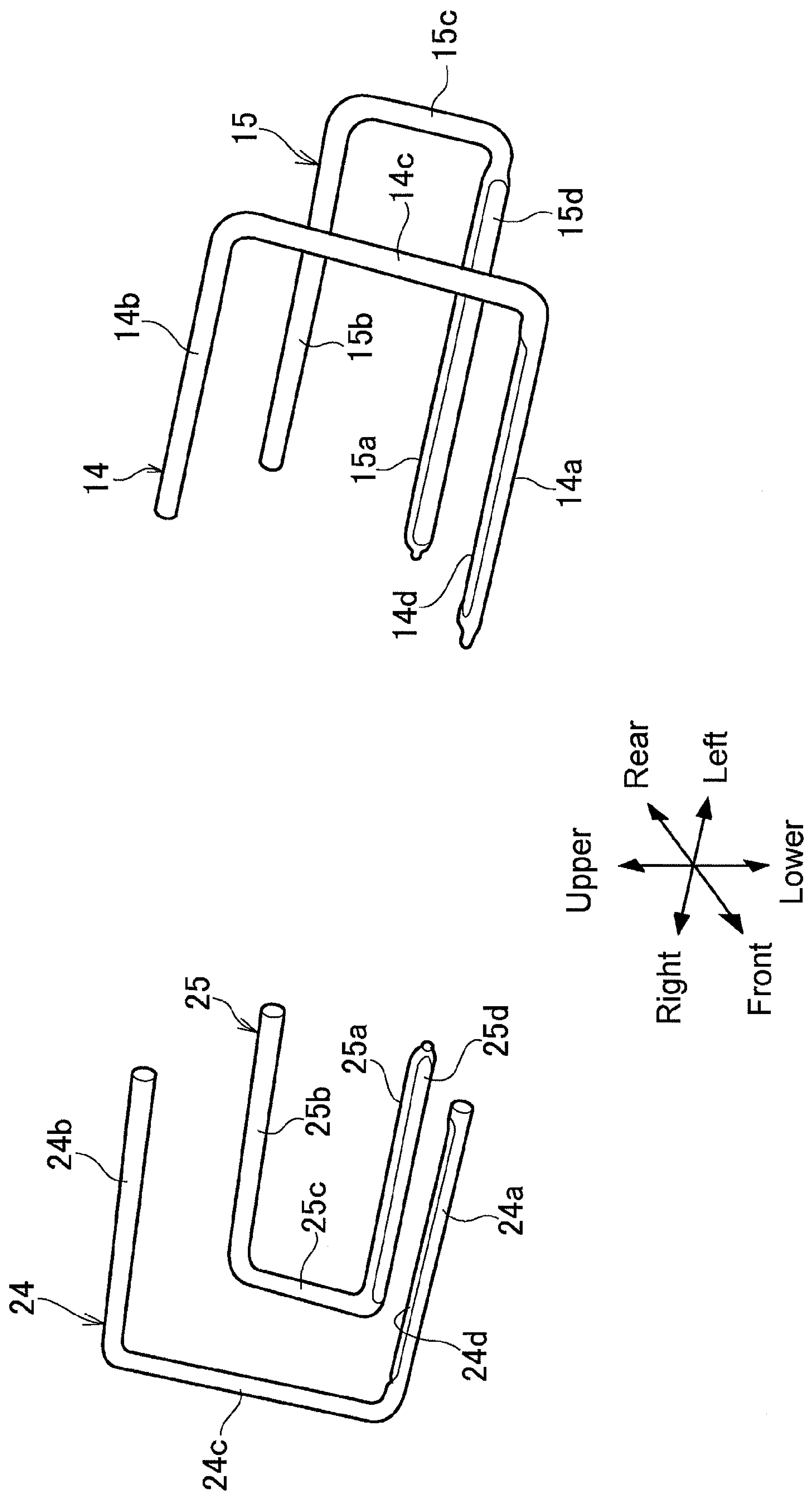


Fig. 4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15
14c
15d
14b
15b
14
15a
14a
14d
Rear
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Upper
Lower
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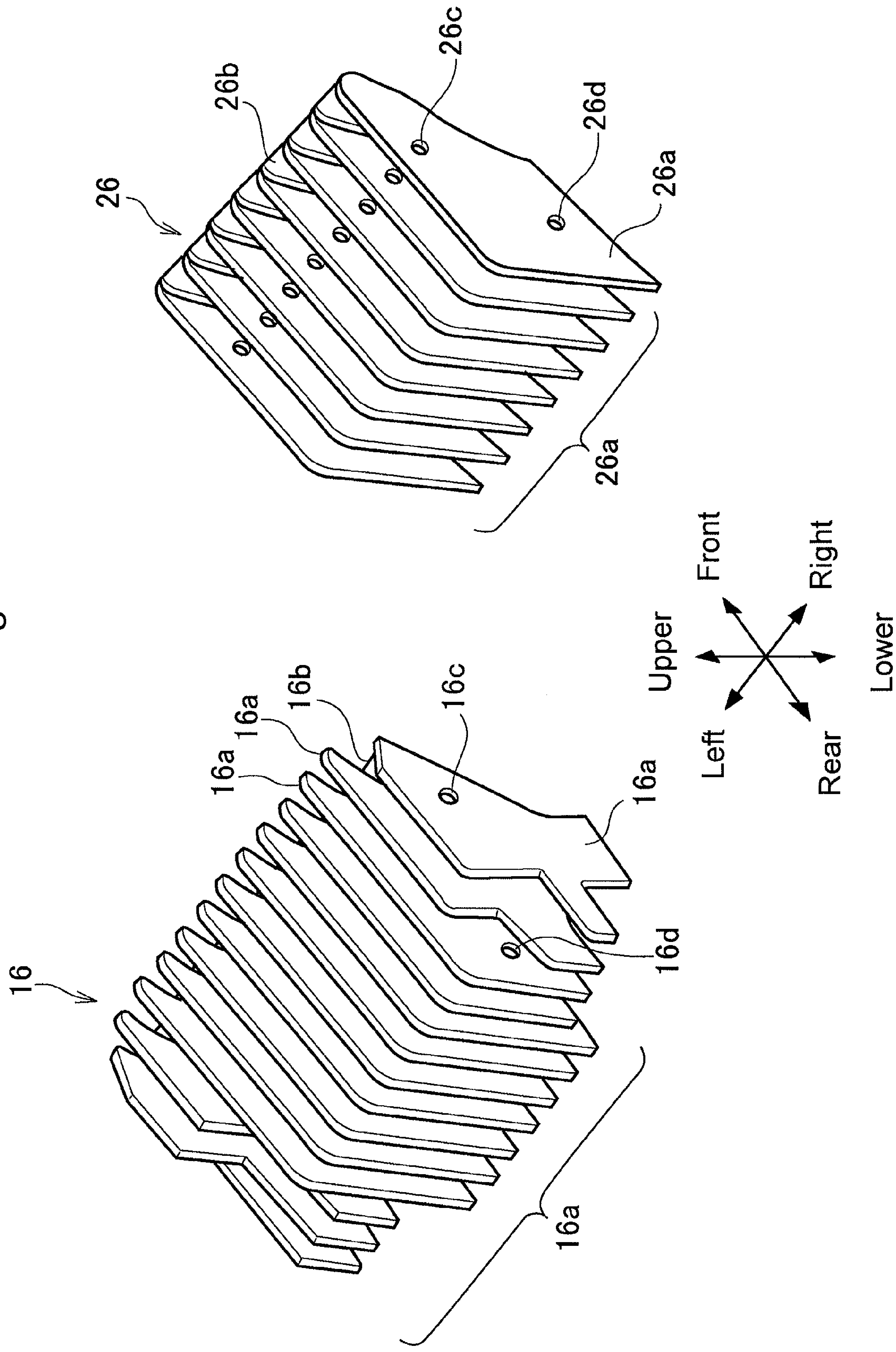
Front
25
25a
25d
25b
24b
25c
24a
24
24d
24c

Fig. 5


26
26a
26b
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16
16a
16b
16c
16d
Front
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Upper
Lower
Left
Rear

Fig. 6

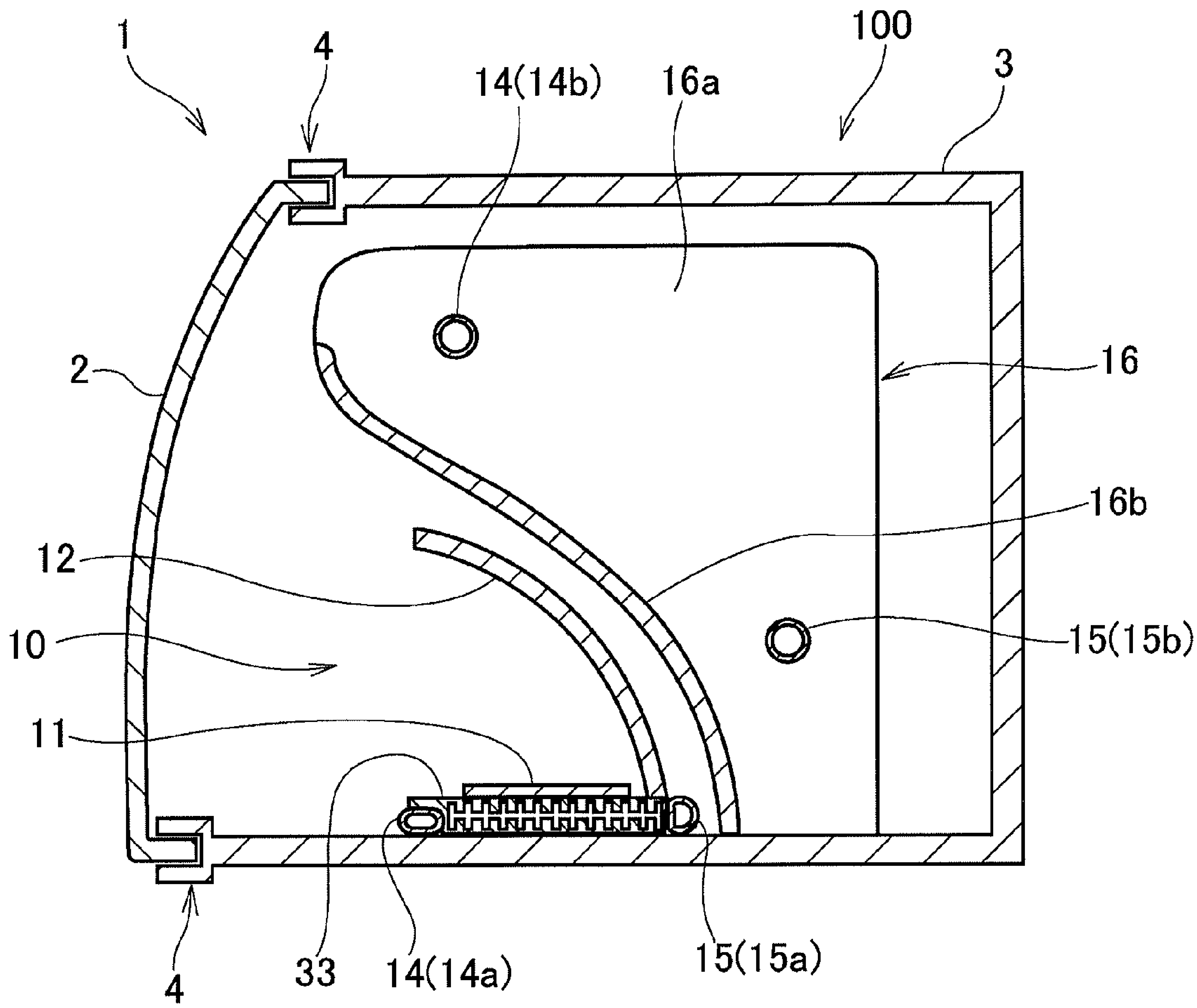
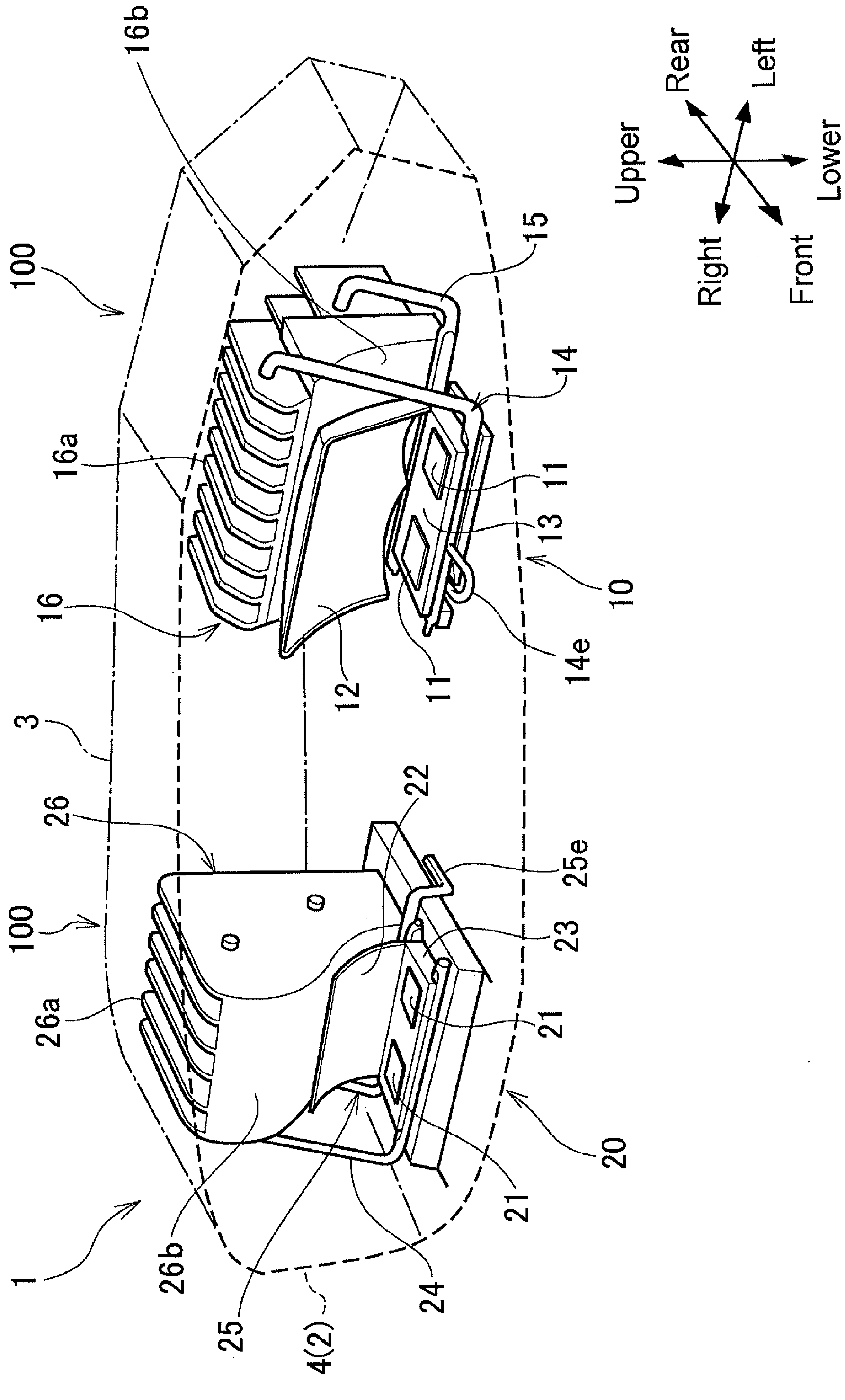


Fig. 7



100
16b
Rear
Left
Upper
Lower
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Front
15
14
16a
11
13
10
16
12
11
14e
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26a
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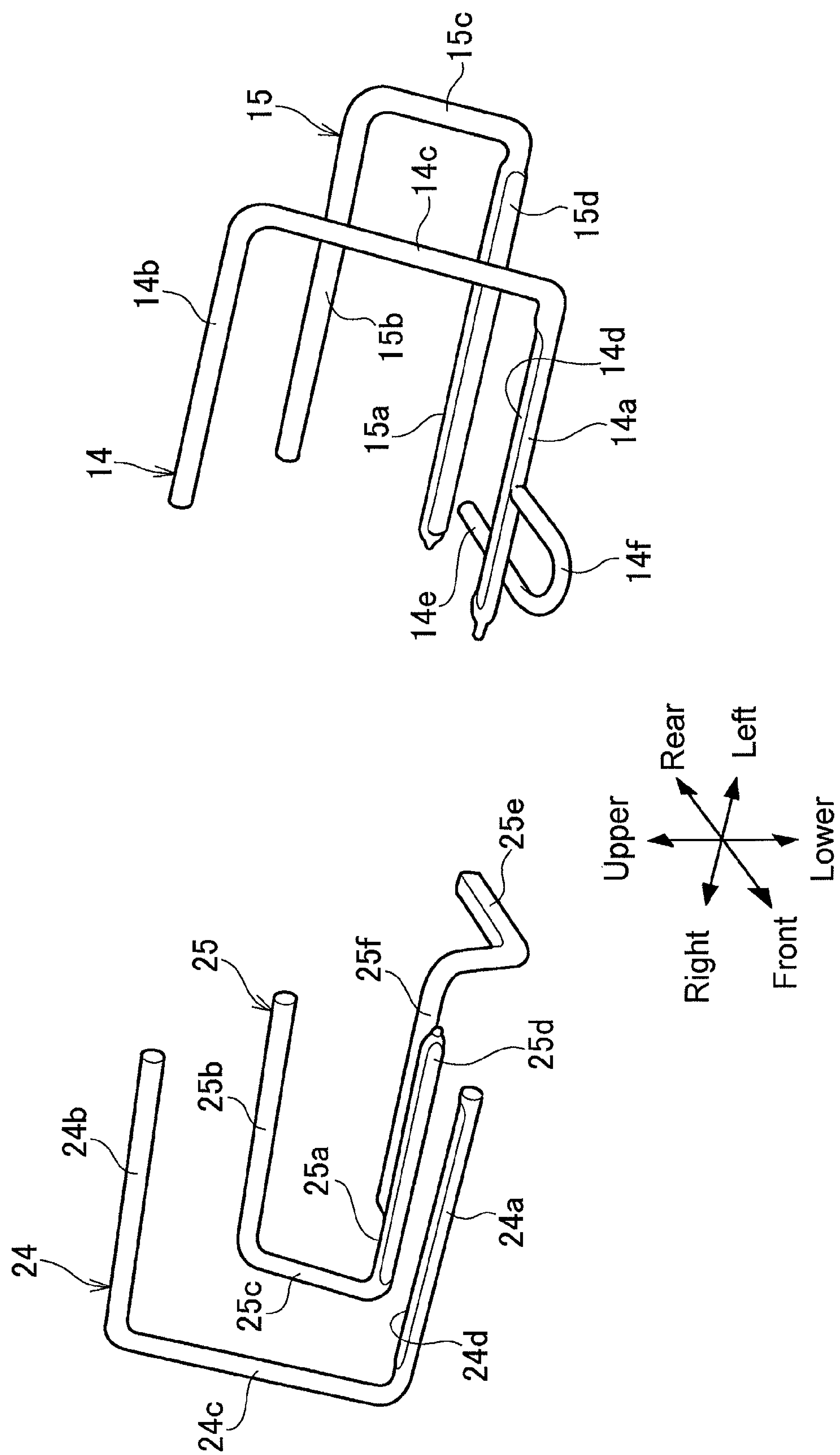
26b
24
25
4(2)

Fig. 8


15c
15
14c
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14f
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25d
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24b
24a
24
25c
24d
24c

Fig. 9

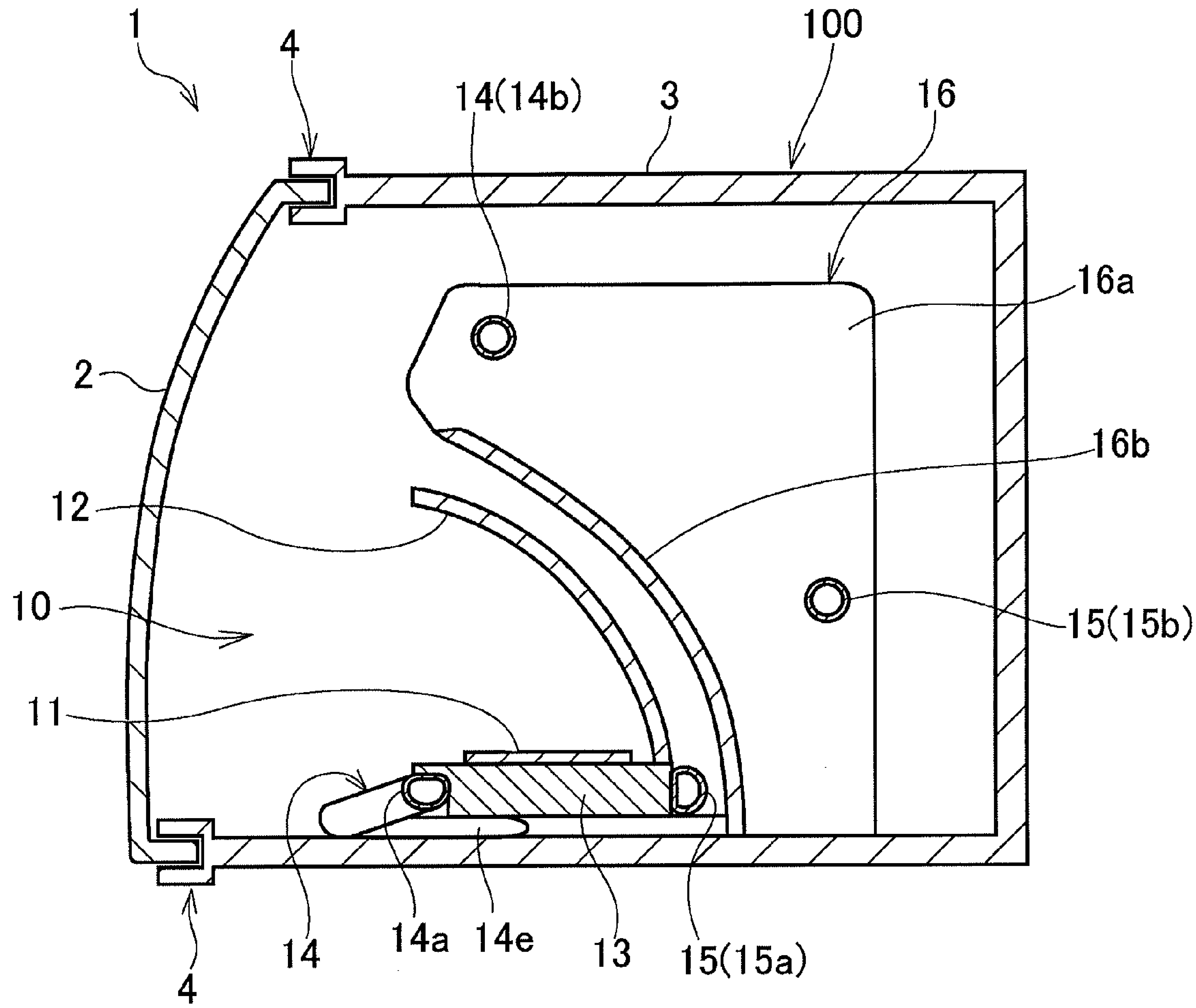


Fig. 10

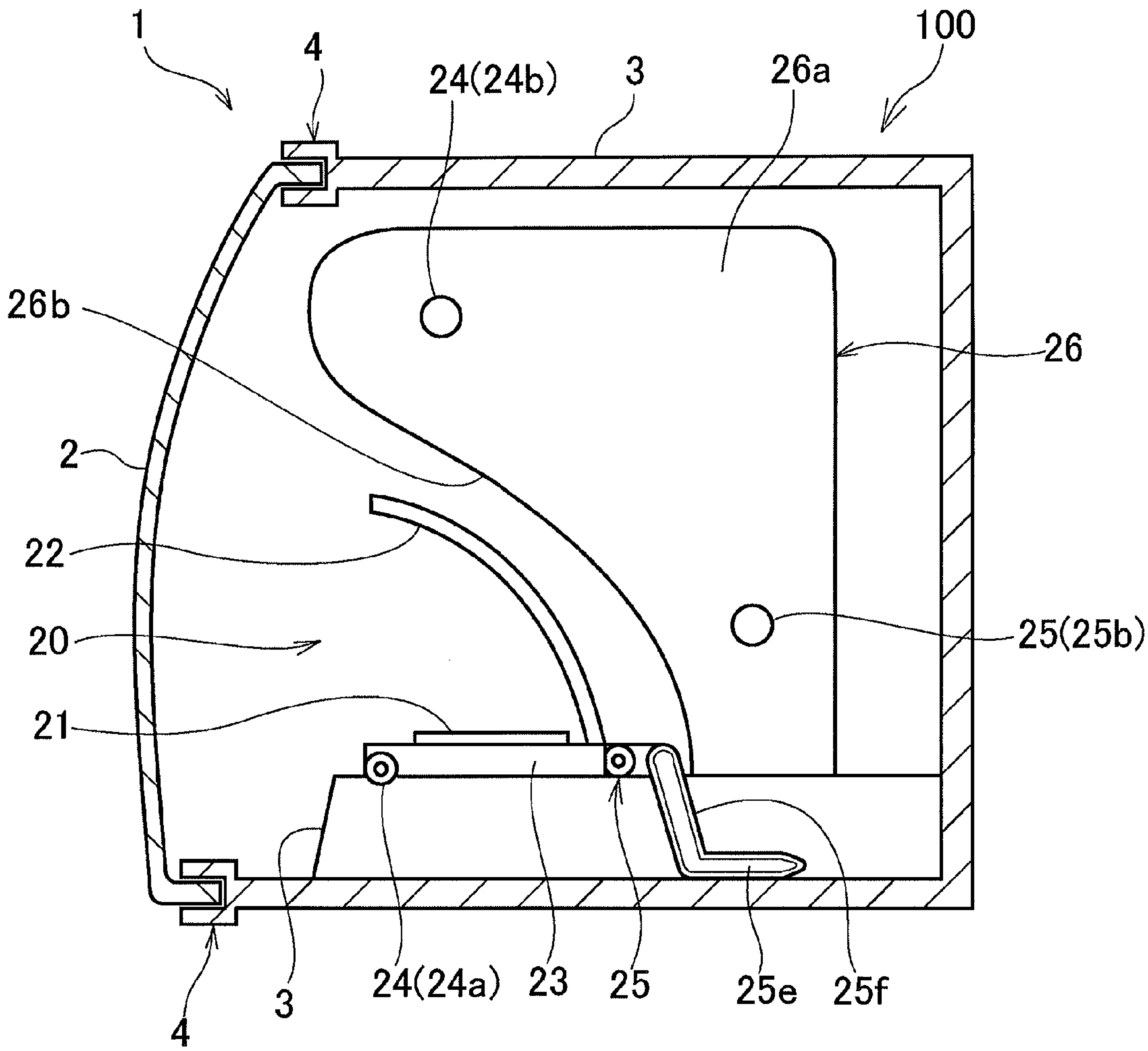
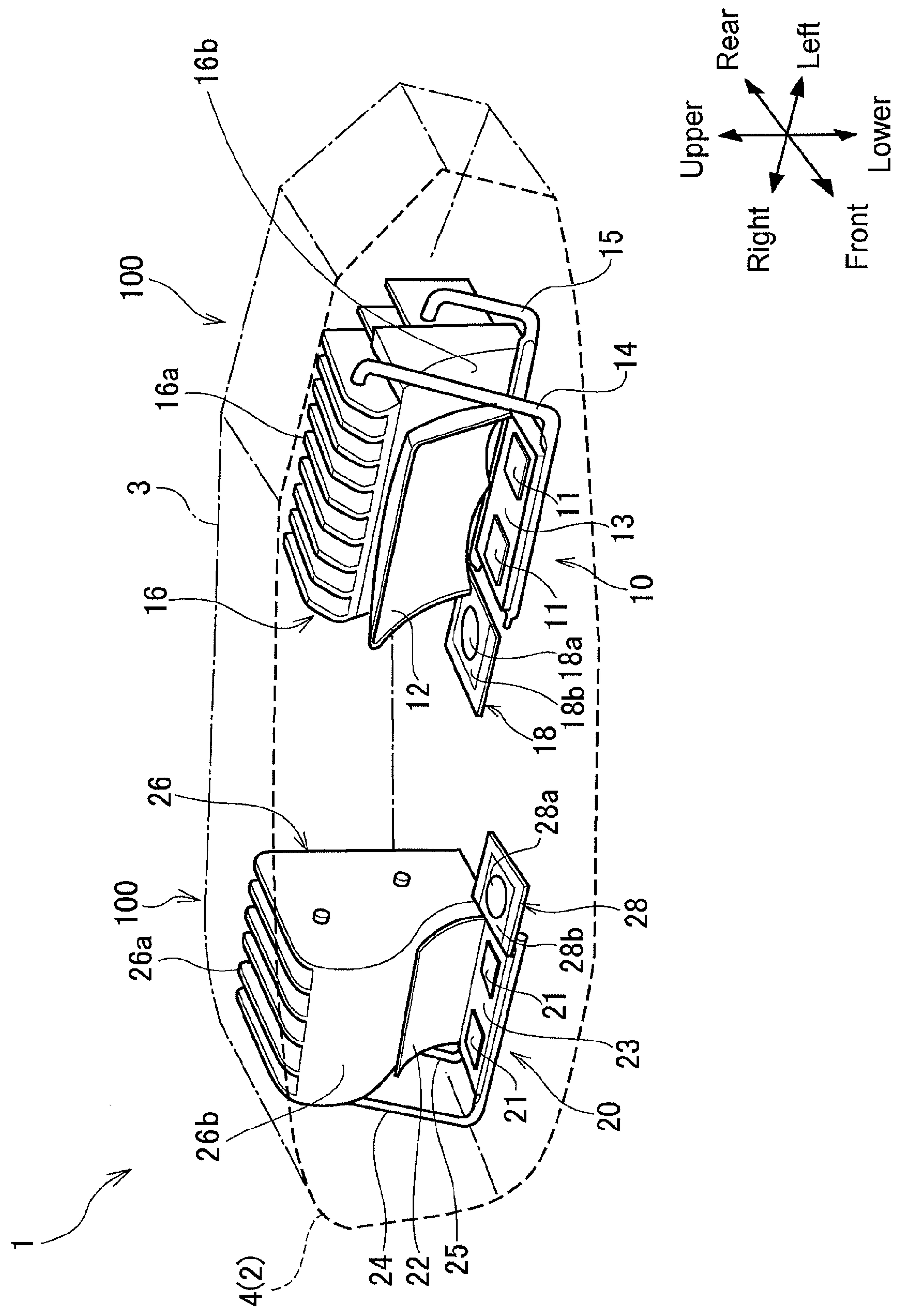


Fig. 11


Rear
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16b
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16a
3
16
15
14
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13
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10
12
18a
18b
18
26
28a
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28b
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26a
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23
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20
26b
24
22
25
4(2)
1

Fig. 12

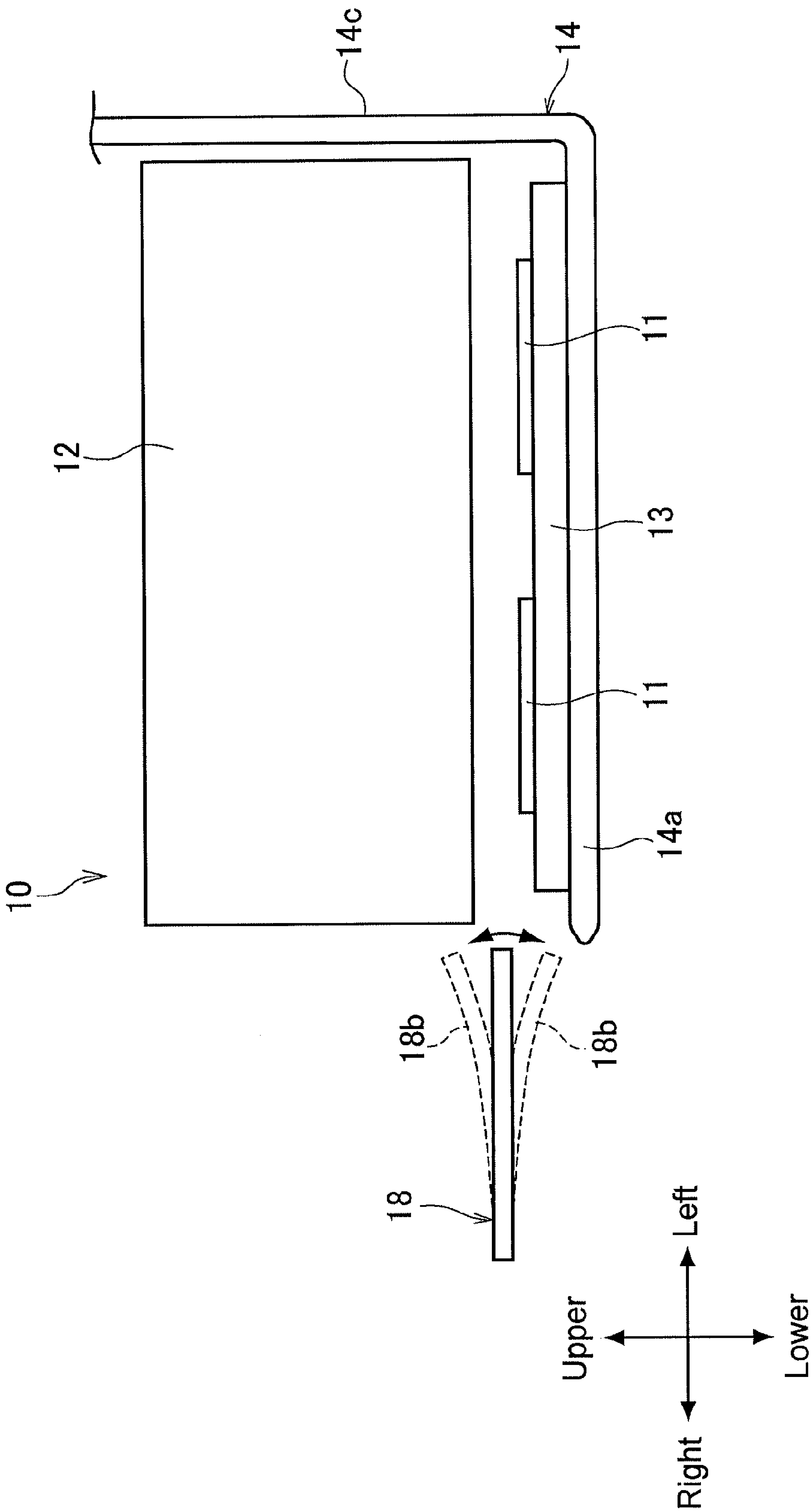
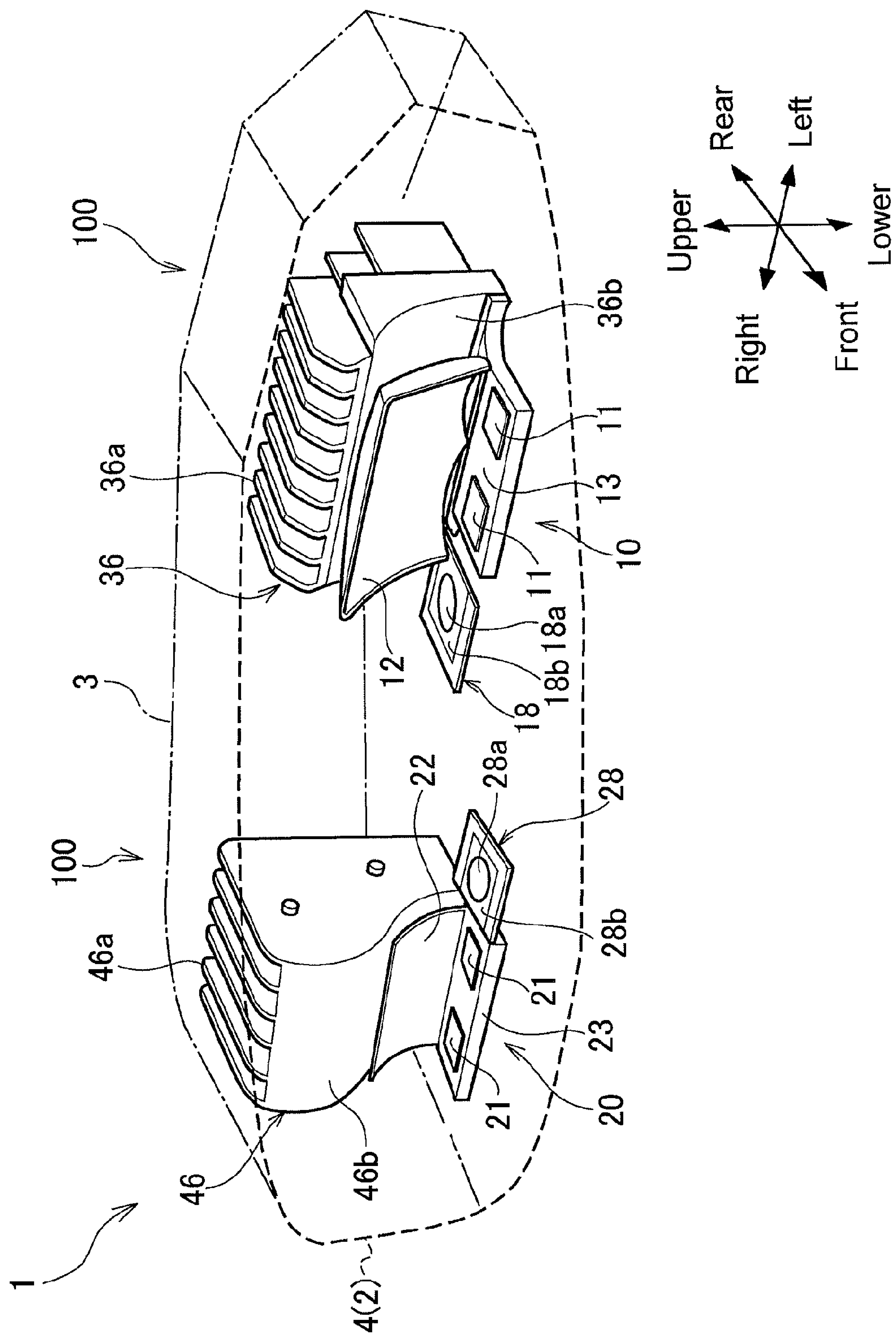


Fig. 13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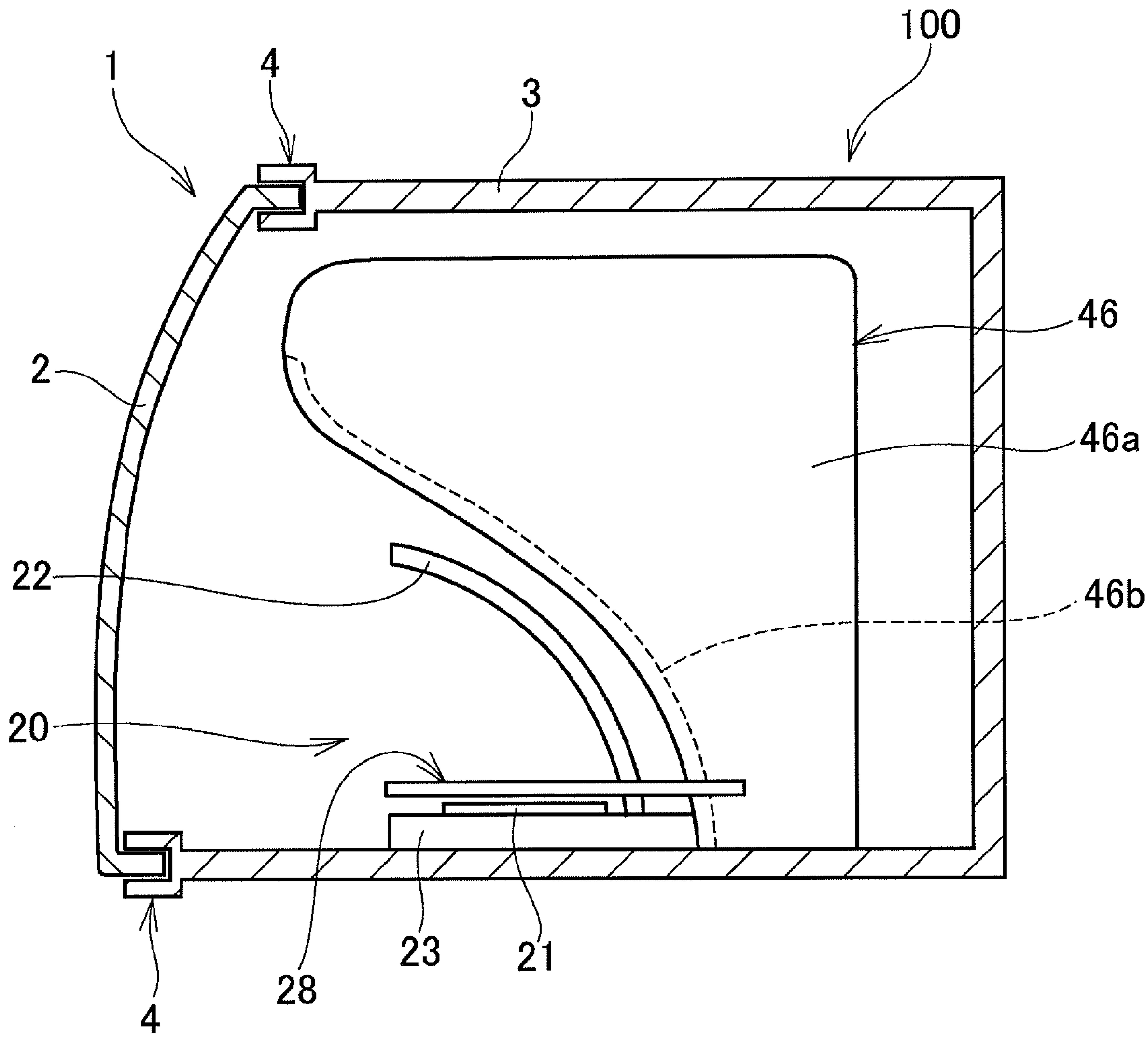
100
100
3
4(2)
36
36a
36b
46
46a
46b
10
11
11
12
13
18
18a
18b
20
21
21
22
23
28
28a
28b
Upper
Lower
Rear
Front
Left
Right

Fig. 14



COOLING DEVICE FOR VEHICLE HEADLIGHTS

The present invention claims the benefit of Japanese Patent Application No. 2013-211852 filed on Oct. 9, 2013 with the Japanese Patent Office, the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND

1. Field of the Invention

The present invention relates to an art of a cooling device for vehicle headlights having a Light Emitting Diode (i.e., an LED).

2. Discussion of the Related Art

A cooling device for vehicle headlights having an LED illuminant is widely used in the conventional art. An electric consumption of the LED is advantageously low, but a calorific value of the LED is rather high and the LED is therefore easily to be heated. That is, since the LED is a semiconductor light source, an operating temperature limit of the LED is not sufficiently high and a usable temperature range thereof has to be limited. If the temperature of the LED exceeds the usable temperature range, durability and brightness thereof will be degraded. Therefore, in order to prevent an excessive temperature rise in the LED, a cooling device for the LED is used in the conventional vehicle headlights.

JP-A-2009-087620 describes a headlight for vehicle in which an exothermic LED is thermally connected to a heat sink as a heat dissipation member through a flexible heat-conductive member. In turn, JP-A-2006-164967 describes a vehicular lighting in which an LED is thermally connected to a heat sink through a loop heat pipe. According to the teachings of both JP-A-2009-087620 and JP-A-2006-164967, fins of the heat sink are exposed on the outside of a housing holding the LED.

Further, JP-A-2010-129543 describes a headlight for vehicle in which an LED is placed on an upper face of the heat sink fitted into a center hole formed in a housing. In addition, a cooling fan is disposed outside of the housing underneath the heat sink so that the heat sink can be cooled by the cooling fan through the center hole.

However, the fins of the heat sink thus exposed on the outside of the housing of the LED may enlarge the vehicle headlights taught by JP-A-2009-087620 and JP-A-2006-164967. In turn, the cooling fan thus integrated with the heat sink may also enlarge the vehicle headlights taught by JP-A-2010-129543.

In addition, according to any of the teachings of the foregoing prior art documents, the external shape of the housing may be restricted by the heat sink arranged on a part of a housing wall in the housing. Therefore, it is difficult to arrange an additional element in the housing of the headlight. That is, even if the headlight is required to be integrated with an additional cooling device, an external shape and a flexibility of arrangement of the additional cooling device may be restricted.

The present invention has been conceived nothing the foregoing technical problems, and it is therefore an object of the present invention is to provide a cooling device for vehicle headlights that effectively cools an LED as a light source while ensuring a flexibility of shape of a housing holding the LED.

SUMMARY OF THE INVENTION

The cooling device for vehicle headlights of the present invention is comprised of: an LED light source held in a

housing sealed with a lens; a reflector that reflects a light emitted from the LED light source; a heat sink that is disposed behind the reflector; and a heat pipe that transports heat generated by the LED light source to the heat sink by a working fluid encapsulated therein. In order to achieve the above-mentioned objective, the cooling device is further provided with a flat cuboid vapor chamber that serves as a heat collector on which the LED light source is mounted. Specifically, the heat sink is comprised of a base covering the reflector from behind and above while keeping a distance therebetween, and a plurality of fins erected vertically to extend from the base in the opposite side of the reflector. Here, a surface area of a lower section of the fin is smaller than that of an upper section. The heat pipe includes: a first heat pipe in which one of end portions is flattened to be contacted with a front long side of the vapor chamber, and the other end portion penetrates through the upper section of the fin while being contacted therewith; and a second heat pipe in which one of end portions is flattened to be contacted with a rear long side of the vapor chamber, and the other end portion penetrates through the upper section of the fin while being contacted therewith. In addition, in the housing, the reflector is isolated from the vapor chamber and the heat pipes.

Specifically, the vapor chamber is comprised of a sealed container, a working fluid held in the container, and a wick that performs a capillary action.

Optionally, a piezo fan may be used in the cooling device to cool the LED light source by sending air over the LED light source. In this case, the piezo fan is disposed at a site not to block an incident light to the reflector emitted from the LED light source.

In addition, each of the first and the second heat pipe may be provided with a branch contacted with an inner face of the housing. In this case, said one of the end portion serves as an evaporating portion, said other end portion serves as a condensing portion, and the branch serves as another condensing portion.

Thus, according to the present invention, the heat sink is held in the housing. Therefore, a flexibility of design of the heat sink and the housing will not be restricted.

As described, according to the present invention, the vapor chamber is used as the heat collector. Therefore, the heat generated by the LED light source can be drawn efficiently by the vapor chamber so that the cooling performance of the cooling device can be enhanced.

As also described, the piezo fan may be used to send air to the LED light source. In this case, specifically, the air is sent over the LED light source by a pivotal movement of the piezo fan caused by an inverse piezo electric effect. A flow rate of the airflow created by the piezo fan is faster than that created by an axial fan so that the LED light source can be cooled more efficiently. Since the piezo fan is situated at a site not to block the incident light to the reflector emitted from the LED light source, a brightness of the headlight will not be decreased.

According to the present invention, the fins are erected vertically while being juxtaposed in the width direction to form a fin array. The condensing portion of the first heat pipe penetrates through the upper section of the fin array, and the condensing portion of the second heat pipe penetrates through the lower section of the fin array. As described, according to the present invention, the area of the lower section of the fin is smaller than that of the upper section. Therefore, a chimney effect can be induced to allow the vapor phase working fluid to flow upwardly through the flow passages between the fins so that the LED light source can be cooled more efficiently.

BRIEF DESCRIPTION OF THE DRAWINGS

Features, aspects, and advantages of exemplary embodiments of the present invention will become better understood with reference to the following description and accompanying drawings, which should not limit the invention in any way.

FIG. **1** is an illustration diagram schematically showing vehicle headlights to which the present invention is applied;

FIG. **2** is a perspective view schematically showing a cooling device for the vehicle headlights according to the first embodiment of the present invention;

FIG. **3** is a cross-sectional view schematically showing the cooling device for a first light shown in FIG. **2**;

FIG. **4** is an illustration diagram showing the heat pipes used in the cooling device shown in FIG. **2**;

FIG. **5** is an illustration diagram showing a heat sink used in the cooling device shown in FIG. **2**;

FIG. **6** is a cross-sectional view schematically showing the cooling device for the vehicle headlights according to the second embodiment of the present invention;

FIG. **7** is a perspective view showing the cooling device for the vehicle headlights according to the third embodiment of the present invention;

FIG. **8** is an illustration diagram showing the heat pipes used in the cooling device shown in FIG. **7**;

FIG. **9** is a cross-sectional view schematically showing the cooling device for the first light shown in FIG. **7**;

FIG. **10** is a cross-sectional view schematically showing the cooling device for the second light shown in FIG. **7**;

FIG. **11** is a perspective view schematically showing the cooling device for the vehicle headlights according to the fourth embodiment of the present invention;

FIG. **12** is a front view showing a motion and an arrangement of a piezo fan for the first light shown in the FIG. **11**;

FIG. **13** is a perspective view schematically showing the cooling device for the vehicle headlights according to the fifth embodiment of the present invention; and

FIG. **14** is a cross-sectional view schematically showing the cooling device for a second light shown in FIG. **2**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

Hereinafter, the present invention will be explained in more details with reference to the accompanying drawings. An example of the vehicle headlights to which the present invention is applied is shown in FIG. **1**. A headlight **1** is comprised of a lens **2** made of resin that is fitted into a front grille of a vehicle Ve, a first light **10** and a second light **20** whose brightness are different respectively. The lights emitted from the first light **10** and the second light **20** penetrate through the lens **2** as an outer lens to illuminate a road ahead.

In the headlight **1** shown in FIG. **1**, the first light **10** is situated outside of the second light **20** in the width direction of the vehicle Ve. In both of the first light **10** and the second light **20**, a light emitting device (to be abbreviated as the "LED" hereinafter) is individually employed as a light source. According to the example, the light emitted from the first light **10** is brighter than that emitted from the second light **20**. Those first and second lights **10** and **20** can be turned on not only independently from each other but also simultaneously according to need.

Here will be explained the first embodiment of the headlight **1** with reference to FIGS. **2** and **3**. FIG. **2** is a perspective view showing an inner structure of the headlight **1**, and FIG. **3** is a cross-sectional view of the first light **10** of the headlight **1**. As shown in FIG. **3** the first light **10** and the second light **20** are arranged in a housing **3**, and a front opening of the housing **3** is closed by the lens **2**. A sealing member **4** is arranged on an opening edge of the housing **3**, and an outer edge of the lens **2** is fitted into the sealing member **4**. Here, a configuration of the sealing member **4** should not be limited to the configuration shown in FIG. **3**, and material of which should also not be limited to the specific material. According to the preferable embodiments of the present invention, resin material **4** is used to form the sealing member. Thus, the housing **3** serves as an outer casing of a unit of the headlight **1** to be fitted into a frame (not shown) of the vehicle Ve. In addition, a ventilation (not shown), e.g., a slit or the like is formed on a wall of the housing **3** so that a communication between an interior space of the housing **3** and an exterior is provided. Here, in FIG. **2**, a dotted-dashed line indicates the housing **3**, and a dashed line indicates the outer edge of the lens **2** or the sealing member **4**.

According to the embodiment shown in FIG. **2**, the first light **10** is provided with a pair of LEDs **11** juxtaposed in the width direction, and the second light **20** is provided with a pair of LEDs **21** juxtaposed in the width direction. For instance, a packaged light source in which an LED chip placed on a square board is connected to a not shown electronic circuit can be used as those LEDs **11** and **21**. Therefore, the LEDs **11** and **21** are activated to emit light by applying a current to the electronic circuit. Accordingly, a definition of the term "LED" in the explanation is the plate like LED package comprising the LED chip and the board. In addition, in order not to expose the LED chip to air, the LED chip is covered with a resin mold.

In the housing **3**, the LEDs **11** and **21** are laid horizontally to emit light upwardly. In order to reflect the light emitted by the LED **11** ahead of the vehicle Ve, the first light **10** is provided with a domed reflector **12** covering the first light **10** from behind and above. Likewise, in order to reflect the light emitted by the LED **21** ahead of the vehicle Ve, the second light **20** is also provided with a reflector **22** covering the second light **20** from behind and above. Here, configurations of the reflectors **12** and **22** may be not only identical to each other but also different from each other.

Next, a cooling device **100** arranged in the housing **3** will be explained hereinafter. The first light **10** and the second light **20** are individually provided with the cooling device **100** to cool the heat generating LEDs **11** and **21**. The cooling device **100** for the first light **10** is adapted to collect the heat resulting from light emission of the LED **11** by a heat collector **13**, and to radiate the heat from the heat sink **16** through a pair of heat pipes **14** and **15**. Likewise, the cooling device **100** for the first light **20** is adapted to collect the heat resulting from light emission of the LED **21** by a heat collector **23**, and to radiate the heat from the heat sink **26** through a pair of heat pipes **24** and **25**. Since the heat sinks **16** and **26** are thus arranged inside of the housing **3**, the heats generated by the LEDs **11** and **21** are radiated to the internal space of the housing **3**.

In the cooling device **100** for the first light **10**, the heat collector **13** is installed on the bottom of the housing **3**, and the LED **11** is mounted on the heat collector **13**. That is, a lower face of the board of the LED **11** and the upper face of the heat collector **13** are contacted tightly to each other so that the heat of the LED **11** can be transferred to the heat collector **13**. In other words, the heat collector **13** is a flat cuboid heat conductive block made of material having high heat conductivity. Therefore, the heat generated by the LED **11** is transferred to the heat collector **13** homogeneously and entirely.

According to the preferred embodiment, the heat collector **13** is disposed longitudinally in a width direction of the vehicle Ve, and a pair of LEDs **11**, **11** are juxtaposed in the width center of the heat collector **13**. Accordingly, the heats of the LEDs **11** are drawn through the upper face of the heat collector **13** and spread radially downwardly in the heat collector **13**.

The heat collector **13** is connected with the heat sink **16** though a pair of heat pipes **14** and **15** so that the heat of the heat collector **13** is transported to the heat sink **16** through the heat pipes **14** and **15**. To this end, a conventional heat pipe in which working fluid encapsulated therein is individually employed as each heat pipes **14** and **15**. In each heat pipe **14**, **15**, the working fluid is evaporated at a heated portion (i.e., at an evaporating portion) and condensed at a heat radiating portion (i.e., at a condensing portion). FIG. **4** shows a structure of each first heat pipe **14** and second heat pipe **15** of the cooling device **100** shown in FIG. **2**.

As illustrated in FIG. **4**, each first heat pipe **14** and second heat pipe **15** are shaped into U-shape. Specifically, the first heat pipe **14** is comprised of an evaporating portion **14***a*, a condensing portion **14***b* extending parallel to the evaporating portion **14***a*, and an insulating portion **14***c* connecting the evaporating portion **14***a* with the condensing portion **14***b*. Likewise, the second heat pipe **15** is comprised of an evaporating portion **15***a*, a condensing portion **15***b* extending parallel to the evaporating portion **15***a*, and an insulating portion **15***c* connecting the evaporating portion **15***a* with the condensing portion **15***b*. Here, the insulating portion **14***c* of the first heat pipe **14** is formed to be longer than the insulating portion **15***c* of the second heat pipe **15** thereby extending a heat transfer distance of the first heat pipe **14** to be longer than that of the second heat pipe **15**. Optionally, the second heat pipe **15** may be formed to have a larger diameter than that of the first heat pipe **14**.

In addition, the evaporating portion **14***a* is partially flattened to form a flat contact surface **14***d* and the evaporating portion **15***a* is partially flattened to form a flat surface **15***d*. Therefore, each contact area between the heat collector **13** and the flat contact surface **14***d* of the first heat pipe **14** and the flat contact surface **15***d* of the second heat pipe **15** are enlarged to enhance heat transfer efficiency therebetween.

Specifically, as shown in FIG. **3**, the flat contact surface **14***d* of the evaporating portion **14***a* is contacted with a front long side of the heat collector **13**, and the flat contact surface **15***d* of the evaporating portion **15***a* is contacted with a rear long side of the heat collector **13**. Therefore, the heat is drawn from the LED **11** through the heat collector **13**, and the working fluids in the evaporating portions **14***a* and **15***a* are evaporated by the heat of the heat collector **13**. On the other hand, the condensing portion **14***b* of the first heat pipe **14** and the condensing portion **15***b* of the second heat pipe **15** individually penetrate through an array of fins **16**.

As shown in FIG. **2**, the heat sink **16** is disposed behind (i.e., in the back side) of the reflector **12**. The heat sink **16** is comprised of a base **16***b* covering the reflector **12** from behind and above, and fins **16***a* erected vertically while being juxtaposed in the width direction to extend from the base **16***b* in the opposite side of the reflector **12**. Accordingly, a plurality of flow passages for vertically letting through the air are formed between the fins **16***a*. An arrangement of the fin allay of the heat sink **16** is shown in FIG. **5**.

As shown in FIG. **5**, a first through-hole **16***c* to which the first heat pipe **14** is inserted is formed on an upper section of each fin **16***a* of the heat sink **16**, and a second through-hole **16***d* to which the second heat pipe **15** is inserted is formed on each fin **16***a* at a lower level than the first through-hole **16***c*. A surface area of the fin **16***a* above the first through-hole **16***c* is larger than that below the second through-hole **16***d*. That is, a heat capacity of the upper section of the fin **16***a* is larger than that of the lower section. In addition, both of the first through-hole **16***c* and the second through-hole **16***d* are formed at levels higher than the heat collector **13**.

The first heat pipe **14** is inserted into each first through-hole **16***c* of the fin allay in a manner such that the condensing portion **14***b* is contacted with an inner circumference of the first through-hole **16***c*. Likewise, the second heat pipe **15** is inserted into each second through-hole **16***d* of the fin allay in a manner such that the condensing portion **15***b* is contacted with an inner circumference of the second through-hole **16***d*. Accordingly, the condensing portions **14***b* and **15***b* are situated above the evaporating portions **14***a* and **15***a*. Here, although the fins **16***a* are contacted to the bottom of the housing **3** in FIG. **3**, the fins **16***a* may be isolated from the bottom of the housing **3**.

In the first heat pipe **14**, the working fluid is evaporated at the evaporating portion **14***a*, and the heat is transported to the condensing portion **14***b* by the vapor of the working fluid to be radiated from the fins **16***a*. Consequently, the working fluid in the vapor phase is condensed into the liquid phase at the condensing portion **14***b*. The working fluid thus condensed is returned to the evaporating portion **14***a* by a capillary force or gravity. Likewise, in the second heat pipe **15**, the working fluid is evaporated at the evaporating portion **15***a*, and condensed into the liquid phase at the condensing portion **15***b* as a result of radiating the heat from the fins **16***a* and returned to the evaporating portion **15***a* by a capillary force or gravity. Thus, in the cooling device **100** for the first light **10**, the LED **11** as a heat-generating member is connected to the heat sink **16** as a radiation device through the heat pipes **14** and **15** to transport the heat therebetween. That is, the heat generated by the LEDs **11** is radiated to the internal space of the housing **3**.

In the cooling device **100** for the second light **20**, the heat collector **23** is installed on the bottom of the housing **3**, and the LED **21** is mounted on the heat collector **23**. That is, a lower face of the board of the LED **21** and the upper face of the heat collector **23** are contacted tightly to each other so that the heat generated by the LED **21** can be conducted to the heat collector **23**. In other words, the heat collector **23** is a flat rectangular heat conductive structure made of material having high heat conductivity. Therefore, the heat generated by the LED **21** is conducted to the heat collector **23** homogeneously and entirely.

According to the preferred embodiment, the heat collector **23** is disposed longitudinally in a width direction of the vehicle Ve, and a pair of LEDs **21**, **21** are juxtaposed in the width center of the heat collector **23**. Accordingly, the heats of the LEDs **21** are conducted to the width center of the upper face of the heat collector **23** and then the heat spread radially downwardly in the heat collector **23**.

The heat collector **23** is connected with the heat sink **26** though a pair of heat pipes **24** and **25** so that the heat of the heat collector **23** is conducted to the heat pipes **24** and **25**, and transported to the heat sink **26** through the heat pipes **24** and **25**. To this end, a conventional heat pipe in which working fluid encapsulated therein is individually employed as each heat pipes **24** and **25**. In each heat pipe **24**, **25**, the working fluid is evaporated at a heated portion (i.e., at an evaporating portion) and condensed at a heat radiating portion (i.e., at a condensing portion). FIG. **4** shows a structure of each first heat pipe **24** and second heat pipe **25** of the cooling device **100** shown in FIG. **2**.

As illustrated in FIG. **4**, each first heat pipe **24** and second heat pipe **25** are shaped into U-shape. Specifically, the first heat pipe **24** is comprised of an evaporating portion **24***a*, a condensing portion **24***b* extending parallel to the evaporating portion **24***a*, and an insulating portion **24***c* connecting the evaporating portion **24***a* with the condensing portion **24***b*. Likewise, the second heat pipe **25** is comprised of an evaporating portion **25***a*, a condensing portion **25***b* extending parallel to the evaporating portion **25***a*, and an insulating portion **25***c* connecting the evaporating portion **25***a* with the condensing portion **25***b*. Here, the insulating portion **24***c* of the first heat pipe **24** is formed to be longer than the insulating portion **25***c* of the second heat pipe **25** thereby extending a heat transfer distance of the first heat pipe **24** to be longer than that of the second heat pipe **25**. Optionally, the second heat pipe **25** may be formed to have a larger diameter than that of the first heat pipe **24**.

In addition, an outer surface of the evaporating portion **24***a* is partially flattened to form a flat surface **24***d* contacted with a front long side of the heat collector **23**. Likewise, an outer surface of the evaporating portion **25***a* is partially flattened to form a flat surface **25***d* contacted with a rear long side of the heat collector **23**. Therefore, each contact area between the heat collector **23** and each heat pipe **24**, **25** can be enlarged to enhance heat transfer efficiency. Thus, the evaporating portion **24***a* of the first heat pipe **24** and the evaporating portion **25***a* of the second heat pipe **25** extend parallel to each other in the width direction across the heat collector **23**.

The heat generated by the LED **21** is conducted individually to the evaporating portions **24***a* and **25***a* at the front and rear long sides of the heat collector **23**, and the working fluids held therein are evaporated by the heat from the LED **21**. On the other hand, the condensing portion **24***b* of the first heat pipe **24** and the condensing portion **25***b* of the second heat pipe **25** individually penetrate through an array of fins **26**.

As shown in FIG. **2**, the heat sink **26** is disposed behind (i.e., in the back side) of the reflector **22**. The heat sink **26** is comprised of a base **26***b* covering the reflector **22** from behind and above, and fins **26***a* erected vertically while being juxtaposed in the width direction to extend from the base **26***b* in the opposite side of the reflector **22**. Accordingly, a plurality of flow passages for vertically letting through the air are formed between the fins **26***a*. An arrangement of the fin allay of the heat sink **26** is shown in FIG. **5**.

As shown in FIG. **5**, a first through-hole **26***c* to which the first heat pipe **24** is inserted is formed on an upper section of each fin **26***a* of the heat sink **26**, and a second through-hole **26***d* to which the second heat pipe **25** is inserted is formed on each fin **26***a* at a lower level than the first through-hole **26***c*. A surface area of the fin **26***a* above the first through-hole **26***c* is larger than that below the second through-hole **26***d*. That is, a heat capacity of the upper section of the fin **26***a* is larger than that of the lower section. In addition, both of the first through-hole **26***c* and the second through-hole **26***d* are formed at levels higher than the heat collector **23**. Here, the heat sink **16** for the first light **10** may be formed in the shape of the heat sink **26** for the second light **20**. Alternatively, the heat sink **16** may be either the same as or different size from the heat sink **26**. For example, the heat sink **16** may be larger than the heat sink **26**.

The first heat pipe **24** is inserted into each first through-hole **26***c* of the fin allay in a manner such that the condensing portion **24***b* is contacted with an inner circumference of the first through-hole **26***c*. Likewise, the second heat pipe **15** is inserted into each second through-hole **26***d* of the fin allay in a manner such that the condensing portion **25***b* is contacted with an inner circumference of the second through-hole **26***d*. Accordingly, the condensing portions **24***b* and **25***b* are situated above the evaporating portions **24***a* and **25***a*. Here, although the fins **26***a* are contacted to the bottom of the housing **3**, the fins **26***a* may be isolated from the bottom of the housing **3**.

In the first heat pipe **24**, the working fluid is evaporated at the evaporating portion **24***a*, and the heat is transported to the condensing portion **24***b* by the vapor of the working fluid to be radiated from the fins **26***a*. Consequently, the working fluid in the vapor phase is condensed into the liquid phase at the condensing portion **24***b*. The working fluid thus condensed is returned to the evaporating portion **24***a* by a capillary force or gravity. Likewise, in the second heat pipe **25**, the working fluid is evaporated at the evaporating portion **25***a*, and condensed into the liquid phase at the condensing portion **25***b* as a result of radiating the heat from the fins **26***a* and returned to the evaporating portion **25***a* by a capillary force or gravity. Thus, in the cooling device **100** for the second light **20**, the LED **21** as a heat-generating member is connected to the heat sink **26** as a radiation device through the heat pipes **24** and **25** to transport the heat therebetween. That is, the heat generated by the LEDs **21** is radiated to the internal space of the housing **3**.

As described, according to the first embodiment of the cooling device for the headlights, the heat sink serving as the heat radiating member is arranged in the housing of the headlights so that the LEDs can be cooled efficiently without blocking lights from the LEDs. In addition, a flexibility of design of the heat sink and the housing will not be restricted. As also described, the condensing portion of each heat pipe individually penetrate through the upper section and the lower section of the fins while being contacted therewith, and the area of the lower section of the fin is smaller than that of the upper section. Therefore, a chimney effect can be induced to allow the vapor phase working fluid to flow upwardly through the flow passages between the fins. Consequently, the heat of the LEDs can be efficiently radiated from the heat sink so that cooling capacity for LEDs can be enhanced. In addition, since the area of the lower section of the fin is thus smaller than that of the upper section, the heat capacity of the lower section of the fins is smaller than that of the upper section. That is, the temperature of the lower section of the fin is raised faster than that of the upper section. Therefore, the upward stream of the working fluid can be further expedited so that the heat of the LEDs can be radiated from the fins efficiently.

The cooling device for vehicle headlights should not be limited to the first embodiment, and may be modified within the spirit of the present invention.

For example, according to the second embodiment of the present invention, a vapor chamber (i.e., a flat heat pipe) is employed as at least any one of the heat collector **13** of the first light **10** and the heat collector **23** of the second light **20** instead of the heat conductive block. Referring now to FIG. **6**, there is shown an example in which the vapor chamber is used as the heat collector in the first light **10**. Here, in the following explanation of the second embodiment, common reference numerals are allotted to the elements identical to those in the first embodiment, and detailed explanation for those elements will be omitted.

As shown in FIG. **6**, according to the second embodiment, a vapor chamber **33** is laid on the bottom of the housing **3**, and the LED **11** is disposed on the upper face of the vapor chamber **33**. The front face of the vapor chamber **33** is contacted with the evaporating portion **14***a* of the heat pipe **14**, and the rear face of the vapor chamber **33** is contacted with the evaporating portion **15***a* of the heat pipe **15**. As the conventional vapor chamber, a small amount of the working fluid is encapsulated in a sealed internal space of the vapor chamber **33**, and a wick is disposed therein. According to the second embodiment, therefore, the heat of the LED **11** can be transported efficiently to the heat sink **16** utilizing the heat transportation property of the vapor chamber **33** so that the cooling performance of the cooling device **100** can be enhanced.

According to the third embodiment of the cooling device, as shown in FIG. **7**, the first heat pipe **14** is modified to contact the condensing portion thereof with the housing **3**. In the following explanation of the third embodiment, common reference numerals are also allotted to the elements identical to those in the foregoing embodiments, and detailed explanation for those elements will also be omitted.

As illustrated in FIG. **7**, in the first light **10**, a second condensing portion **14***e* is extended from the first heat pipe **14** to be contacted with the bottom of the housing **3**. Also, in the second light **20**, a second condensing portion **25***e* is extended from the second heat pipe **25** to be contacted with the bottom of the housing **3**. Details of structures of heat pipes **14**, **15**, **24**, and **25** of the third embodiment are shown in FIG. **8**.

As shown in FIG. **8**, in the first heat pipe **14** of the first light **10**, a branch is extended from an intermediate portion of the evaporating portion **14***a* contacted with the heat collector **13** to protrude in the forward direction, and bent downwardly backwardly at a predetermined portion to form a U-shaped branch. In the U-shaped branch, specifically, a portion between the evaporating portion **14***a* and the bent portion serves as a second insulting portion **14***f*, and a portion extending further than the bent portion is contacted with the housing **3** to serve as the second condensing portion **14***e*. Thus, the evaporating portion **14***a* is connected to the first condensing portion **14***b* via the first insulating portion **14***c*, and also connected to the second condensing portion **14***e* via the second insulating portion **14***f*.

In turn, in the second heat pipe **25** of the second light **20**, a branch is extended in parallel with the evaporation portion **25***a* contacted with the heat collector **23** from an intermediate portion, and a leading end of the branch is bent downwardly and further bent backwardly to form an L-shaped leading end. In the branch, specifically, a portion extending along the evaporating portion **25***a* serves as a second insulting portion **25***f*, and a portion of the L-shaped leading end extending backwardly along the bottom of the housing **3** serve as the second condensing portion **25***e*. Thus, the evaporating portion **25***a* is connected to the first condensing portion **25***b* via the first insulating portion **25***c*, and also connected to the second condensing portion **25***e* via the second insulating portion **25***f*.

As shown in FIG. **9**, in the first heat pipe **14**, the first condensing portion **14***b* penetrates through an array of fins **16***a* while being contacted thereto, and the second condensing portion **14***e* is contacted with the bottom of the housing **3**. As also shown in FIG. **10**, in the second heat pipe **25**, the first condensing portion **25***b* penetrates through an array of fins **26***a* while being contacted thereto, and the second condensing portion **25***e* is contacted with the bottom of the housing **3**. Thus, both of the first heat pipe **14** and the second heat pipe **15** conduct the heats to different objects.

Thus, according to the third embodiment of the cooling device for the headlights, each heat pipe is individually provided with the branch functioning as the second condensing portion contacted with the housing. Accordingly, the heat radiating capacity of each condensing portion can be increased so that the heat transporting capacity of each first and second heat pipe can be enhanced to cool the LEDs effectively.

The structure of each branch may be modified arbitrarily in a manner such that the second condensing portion of the first heat pipe is contacted with the housing, and that the second condensing portion of the second heat pipe is contacted with the housing.

According to the fourth embodiment, as shown in FIG. **11**, the cooling device is provided with a fan for cooling the LEDs by blowing air. In the following explanation of the fourth embodiment, common reference numerals are also allotted to the elements identical to those in the foregoing embodiments, and detailed explanation for those elements will also be omitted.

As illustrated in FIG. **11**, the first light **10** is provided with a piezo fan **18** for sending air to the LED **11**, and the second light **20** is provided with a piezo fan **28** for sending air to the LED **21**. Each piezo fan **18**, **28** is individually provided with a plate-like pivotal fan **18***b*, **28***b* individually having a piezoelectric element **18***a*, **28***a*. Accordingly, a pivotal movement of each pivotal fan **18***b*, **28***b* is achieved by energizing the piezoelectric element **18***a*, **28***a* to cause an inverse piezoelectric effect thereby sending airflow to the surface of the LED **11**, **21**. To this end, each piezo fan **18**, **28** is individually connected to an electronic circuit (not shown).

The piezo fan **18** is arranged in a manner not to block the incident light to the reflector **12** emitted from the LED **11** As shown in FIG. **12**, the piezo fan **18** is disposed inside of the collector **13** in the width direction at a vertically higher level than the LED **11**. As described, the vertical pivotal movement of the pivotal fan **18***b* is achieved by energizing the piezoelectric element **18***a* to cause an inverse piezoelectric effect. That is, the piezo fan **18** is disposed on the opposite side of the insulating portions **14***c* and **15***c* of the heat pipes **14** and **15**.

Specifically, the piezo fan **18** is disposed at a site not to intervene in the reflection of the light of the LED **11** by the reflector **12**. In other words, the piezo fan **18** is arranged out of a reflection range of the reflector **12** in order not to block the light illuminating the road ahead of the vehicle.

Likewise, the piezo fan **28** is arranged in a manner not to block the incident light of the second light **20** illuminating road ahead. The piezo fan **28** is disposed outside of the collector **23** in the width direction at a vertically higher level than the LED **21**. The vertical pivotal movement of the pivotal fan **28***b* is also achieved by energizing the piezoelectric element **28***a* to cause an inverse piezoelectric effect. That is, the piezo fan **28** is disposed on the opposite side of the insulating portions **24***c* and **25***c* of the heat pipes **24** and **25**.

Thus, according to the fourth embodiment of the cooling device for the headlights, the LED can be cooled by sending the air from the piezo fans over the surface of the LED. In addition, a flow rate of the airflow created by the piezo fan is faster than that created by an axial fan so that the LED can be cooled more efficiently.

The location of each piezo fan should not be limited to the above-explained site. For example, the piezo fan may also be disposed on the opposite side of the heat collector where the insulating portion of the heat pipe extends. Alternatively, the piezo fan may also be situated above the reflector to send air vertically to the LEDs.

According to the fifth embodiment of the present invention, as shown in FIG. **13**, the cooling device is adapted to transport the heat of the LED to the heat sink without using the heat pipe. In the following explanation of the fifth embodiment, common reference numerals are also allotted to the elements identical to those in the foregoing embodiments, and detailed explanation for those elements will also be omitted.

According to the fifth embodiment, heat sinks **36** and **46** individually made of high heat conductive aluminum alloy (e.g. DMS-1) are employed instead of the above explained heat sinks **16** and **26**. Specifically, the heat sink **36** of the first light **10** is comprised of a plurality of fins **36***a*, and the heat sink **46** of the second light **20** is comprised of a plurality of fins **46***a*.

As shown in FIG. **13**, the heat sink **36** is disposed behind the reflector **12**. The heat sink **36** is comprised of a base **36***b* covering the reflector **12** from behind, and fins **36***a* erected vertically while being juxtaposed in the width direction to extend from the base **36***b* in the opposite side of the reflector **12**. Accordingly, a plurality of flow passages for vertically letting through the air are formed between the fins **36***a*. According to the fifth embodiment, the heat collector **13** is attached to the lower portion of the base **36***b* to protrude horizontally ahead of the base **36***b*. Optionally, the heat collector **13** may also be formed of DMS-1. The LEDs **11** are disposed on the heat collector **13** so that the heats of the LEDs **11** are transported to the fin **36***a* through the base **36***b*.

In turn, the heat sink **46** is disposed behind the reflector **12**. The heat sink **46** is comprised of a base **46***b* covering the reflector **12** from behind, and fins **46***a* erected vertically while being juxtaposed in the width direction to extend from the base **46***b* in the opposite side of the reflector **12**. Accordingly, a plurality of flow passages for vertically letting through the air are formed between the fins **46***a*. According to the fifth embodiment, the heat collector **23** is attached to the lower portion of the base **46***b* to protrude horizontally ahead of the base **46***b*. As described, the heat collector **23** may also be formed of DMS-1. The LEDs **21** are also disposed on the heat collector **23** so that the heats of the LEDs **21** are transported to the fin **46***a* through the base **46***b*.

The piezo fan **18** of the first light **10** may be disposed on any of lateral sides of the heat collector **13**. Likewise, the piezo fan **28** of the second light **20** may also be disposed on any of lateral sides of the heat collector **23**. Specifically, as shown in FIG. **13**, the piezo fan **18** is arranged on the inner side of the heat collector **13** in the width direction, and the piezo fan **28** is arranged on the outer side of the heat collector **23** in the width direction.

According to the fifth embodiment, since the heat sinks **36** and **46** are made of DMS-1, the heat conductivity of the heat sinks can be enhanced so that the LEDs can be cooled more effectively. In addition, since the heat pipes are not used in this embodiment, a required space of the housing to hold the heat sink can be reduced so that the headlight can be downsized.

The cooling device of the present invention may also be applied to headlights of any of transportation carriers, e.g., automobiles, railway vehicle, ocean ships and vessels, aircraft and so on.

What is claimed is:

1. A cooling device for vehicle headlights, comprising:

an LED light source held in a housing sealed with a lens;

a reflector that reflects a light emitted from the LED light source;

a heat sink that is disposed behind the reflector;

a heat pipe that transports heat generated by the LED light source to the heat sink by a working fluid encapsulated therein;

a flat cuboid vapor chamber that serves as a heat collector on which the LED light source is mounted;

wherein the heat sink is comprised of a base covering the reflector from behind and above while keeping a distance therebetween, and a plurality of fins erected vertically to extend from the base in the opposite side of the reflector;

wherein a surface area of lower section of the fin is smaller than that of an upper section;

wherein the heat pipe includes

a first heat pipe in which one of end portions is flattened to be contacted with a front long side of the vapor chamber, and the other end portion penetrates through the upper section of the fin while being contacted therewith, and

a second heat pipe in which one of end portions is flattened to be contacted with a rear long side of the vapor chamber, and the other end portion penetrates through the upper section of the fin while being contacted therewith; and

wherein the reflector is isolated from the vapor chamber and the heat pipes.

2. The cooling device for vehicle headlights as claimed in claim **1**, wherein the vapor chamber is comprised of:

a sealed container;

a working fluid held in the container; and

a wick that performs a capillary action.

3. The cooling device for vehicle headlights as claimed in claim **2**, further comprising:

a piezo fan that cools the LED light source by sending air over the LED light source;

wherein the piezo fan is disposed at a site not to block an incident light to the reflector emitted from the LED light source.

4. The cooling device for vehicle headlights as claimed in claim **3**,

wherein each of the first and the second heat pipe is further comprised of a branch contacted with an inner face of the housing; and

wherein said one of the end portion serves as an evaporating portion, said other end portion serves as a condensing portion, and the branch serves as another condensing portion.

5. The cooling device for vehicle headlights as claimed in claim **2**,

wherein each of the first and the second heat pipe is further comprised of a branch contacted with an inner face of the housing; and

wherein said one of the end portion serves as an evaporating portion, said other end portion serves as a condensing portion, and the branch serves as another condensing portion.

6. The cooling device for vehicle headlights as claimed in claim **1**, further comprising:

a piezo fan that cools the LED light source by sending air over the LED light source;

wherein the piezo fan is disposed at a site not to block an incident light to the reflector emitted from the LED light source.

7. The cooling device for vehicle headlights as claimed in claim **6**,

wherein each of the first and the second heat pipe is further comprised of a branch contacted with an inner face of the housing; and

wherein said one of the end portion serves as an evaporating portion, said other end portion serves as a condensing portion, and the branch serves as another condensing portion.

8. The cooling device for vehicle headlights as claimed in claim **1**,

wherein each of the first and the second heat pipe is further comprised of a branch contacted with an inner face of the housing; and

wherein said one of the end portion serves as an evaporating portion, said other end portion serves as a condensing portion, and the branch serves as another condensing portion.

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